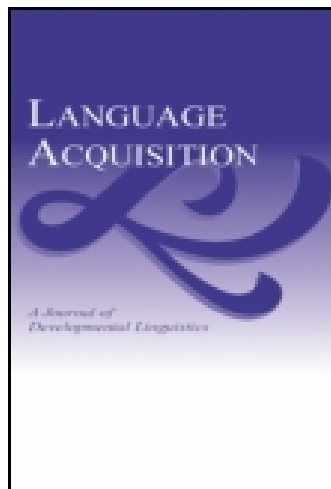


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## Language Acquisition

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/hlac20>

### The Acquisition of Logical Connectives in Child Mandarin

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Accepted author version posted online: 31 Jan 2014. Published online: 11 Mar 2014.

To cite this article: Yi (Esther) Su (2014) The Acquisition of Logical Connectives in Child Mandarin, Language Acquisition, 21:2, 119-155, DOI: [10.1080/10489223.2014.884568](https://doi.org/10.1080/10489223.2014.884568)

To link to this article: <http://dx.doi.org/10.1080/10489223.2014.884568>

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## ARTICLES

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# The Acquisition of Logical Connectives in Child Mandarin

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This study investigates 2–5-year-old Mandarin-speaking children’s interpretation of the disjunction word *huozhe* (‘or’) in two positions in *ruguo* (‘if’)-conditional statements, i.e., in the antecedent clause versus in the consequent clause. The findings from three experiments show that the meanings children assign to disjunction and to *ruguo*-conditionals conform closely to the meanings that are assigned to the corresponding logical connectives in classical logic. Experiment 1 demonstrates that children assign an inclusive-*or* interpretation to disjunction in both the antecedent clause and in the consequent clause of conditional statements, whereas adults assign an exclusive-*or* interpretation to disjunction when it appears in the consequent clause of conditional statements. The findings of Experiment 2 provide evidence of children’s adherence to a putative semantic universal—that disjunction licenses a conjunctive entailment in the antecedent clause of conditional statements, but not in the consequent clause. It is shown in Experiment 3, moreover, that children’s knowledge doesn’t stem from their mistaking disjunction as conjunction. Because the logical meanings of connectives emerge early in the course of language acquisition, and without decisive evidence from the adult input, these findings suggest that children draw upon an innate logical vocabulary at the initial stages of language acquisition.

## 1. INTRODUCTION

Logical connectives include the English words *and*, *or*, and *if*, and their counterparts in Mandarin Chinese: *he*, *huozhe*, and *ruguo*. When these words are combined in sentences, they express complex logical relationships that serve as the foundation of formal principles of reasoning. For more than four decades, children’s knowledge of logical connectives has mainly attracted the interest of scholars from the literature on logical reasoning (e.g., [Braine & Rumain 1983](#)). Although many developmental studies have examined children’s reasoning using sentences with logical

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connectives (e.g., Braine & Romain 1981; Paris 1973; Scholnick & Wing 1991), few studies have directly assessed the meanings children assign to these connectives or how children acquire these meanings. Recent studies of child language have begun to address these issues and have led to a more detailed picture of children's acquisition of the meanings of logical connectives. The findings from these studies, moreover, help adjudicate between two differing perspectives about the nature of language acquisition, including the nature of the acquisition of the meanings of logical connectives. Two main issues frame the debate: (1) whether or not children initially interpret logical connectives in the same way as the corresponding expressions are interpreted in classical logic, and (2) whether the meanings children assign to logical connectives are innately specified or are learned from experience.

Working within the theory of Universal Grammar (e.g., Chomsky 1965, 1986, 1995), some researchers have proposed that children are endowed with innate linguistic knowledge of the meanings of certain logical expressions and that this knowledge is directly related to the truth conditions that are assigned to the corresponding expressions in classical logic. This account is known as *logical nativism* (Crain 2008, 2012; Crain & Khlentzos 2008, 2010). According to logical nativism, the machinery for generating the meanings of sentences that contain logical expressions, including logical connectives (e.g., *and*, *or*, *if*) and quantificational expressions (e.g., *every*, *some*, *nobody*), is innately specified as part of the human biological blueprint for language acquisition (Crain, Gualmini & Pietroski 2005; Crain & Pietroski 2002; Fodor 1975, 1980; Macnamara 1986). On this account, the semantic values of these logical expressions are part of Universal Grammar that language learners draw upon in the course of language acquisition (Chierchia et al. 1998; Crain, Gualmini & Pietroski 2005; Crain, Gualmini & Meroni 2000; Crain & Pietroski 2002; see Chierchia & McConnell-Ginet 2000). Universal Grammar determines the initial stage of language development, so young children learning any language are expected to know the truth conditions associated with these logical words as soon as they have figured out which linguistic expressions in the local languages map onto the corresponding logical operators (Crain 2008, 2012; Crain & Khlentzos 2008, 2010).

An alternative account of the acquisition of the meanings of logical connectives is formulated on the basis of the usage-based model of language acquisition (a.k.a. constructionist, experience-based, or item-based account) (e.g., Goldberg 2006; Tomasello 2003). This account maintains that children have no innate knowledge of the meanings of logical connectives. Instead, the meanings of logical connectives are learned from experience, using general cognitive mechanisms (Morris 2008; see Diessel 2004; Elman 2009; Gentner & Namy 2006; Goldberg 2006; Reali & Christiansen 2004; Tomasello 2003). On this account, children's initial interpretations of logical connectives do not necessarily correspond to the meanings associated with these logical connectives in classical logic. Based on research findings, advocates of the usage-based account contend that the meanings children initially assign to logical connectives are restricted to "simple, non-inferential uses" that do not include "functions of formal logic" (e.g., Morris 2008). These meanings are acquired first because they are the most frequent uses of logical connectives by adults in children's natural language environment. The broader range of uses of logical connectives, including the kinds of "formal" uses that are associated with logical connectives in classical logic are acquired late in the course of language development (Morris 2008; see Diessel 2004; Evers-Vermeul & Sanders 2009; MacWhinney 2002; Tomasello 2003; Veen et al. 2009). Because children are not endowed with innate knowledge of the meanings of logical connectives, wide variation in the meanings children assign to logical expressions across languages is

anticipated. This variation reflects the frequency of linguistic input children encounter in their particular language community (Goldberg 2003, 2006).

The present study investigates the meanings that Mandarin-speaking children assign to the disjunction word *huozhe* ‘or’ in *ruguo* ‘if’-conditional statements. The main research question is whether or not the meanings assigned to these logical connectives in Mandarin Chinese conform to the meanings of the corresponding operators in classical logic. To investigate this, we presented children with conditional statements that contained disjunction in either the antecedent clause or in the consequent clause. These sentences are more complex than those investigated in the literature by proponents of the usage-based account, which mainly focused on children’s uses of logical connectives in isolation (Morris 2008; Veen et al. 2009).

We chose to investigate children’s understanding of these more complex structures for two reasons. First, the interpretation of disjunction in the two clauses of conditional statements is known to be influenced both by semantic principles and by pragmatic principles (Chierchia 2004; Noveck et al. 2002; Crain 2012; Crain, Khlentzos & Thornton 2010), a combination of which is critical to our understanding of the acquisition of the meanings of logical connectives. Second, these complex structures are highly infrequent in the input, yet they have been shown as representative structures reflecting the overlap between classical logic and human languages (Crain 2008, 2012; Crain & Khlentzos 2008, 2010). We pursue this line of research on the contributions classical logic makes to human languages, with a particular focus on child language. If young children, across languages, assign meanings to logical connectives in human languages which parallel that of the corresponding expressions in classical logic, and if children’s knowledge of these meanings is not likely to be drawn from their linguistic experience (Crain 1991; Crain, Goro & Thornton 2006), then this would support the logical nativist account and would be evidence against the usage-based account.

The remainder of the article is structured as follows. The next section provides the theoretical background for the interpretation of disjunction in conditional statements. Then we present the different empirical predictions made by the logical nativist account versus the usage-based account on the acquisition of disjunction in conditional statements. Following that, we review prior studies on children’s acquisition of the meanings of disjunction and conditionals. We proceed then to report the findings of three experiments on Mandarin-speaking children’s interpretation of *huozhe* when it appears in the two clauses of *ruguo*-conditional statements.

## 2. LINGUISTIC BACKGROUND: DISJUNCTION AND CONDITIONALS

This section first introduces the interpretation of disjunction in classical logic and in human languages. Then we discuss the interaction between disjunction and the two clauses of conditional statements.

### 2.1. The Interpretation of Disjunction in Logic and in Human Languages

In classical logic, the disjunction operator  $\vee$  has the truth conditions associated with inclusive-*or*, such that a statement of the form  $A \vee B$  is true (i) if  $A$  alone is true, (ii) if  $B$  alone is true, and (iii) if both  $A$  and  $B$  are true. This third case runs counter to the conventional usage of disjunction by adults. For example, suppose someone says *Amy brought cake or ice cream to the party*.

According to the truth conditions of classical logic, this statement would be true if Amy brought both cake and ice cream to the party. However, in daily conversation, adults normally interpret *Amy brought cake or ice cream to the party* to mean that Amy brought either cake or ice cream to the party, but not both. That is, disjunction is assigned the truth conditions that are associated with exclusive-or (i.e., *A or B, but not both A and B*).

This apparent deviation of the interpretation of disjunction in human languages from that in classical logic has been explained by invoking pragmatic principles that govern conversations, rather than as a fundamental difference in the truth conditions of disjunction between human languages and classical logic (Grice 1975, 1989). Specifically, the application of pragmatic principles in human languages can result in the reduction of certain truth conditions that are available to logical connectives in classical logic. On this account, the “basic” meaning of disjunction words in human languages and in classical logic is the same (namely, inclusive-or). However, there is a “derived” meaning of disjunction words in human languages, but not in classical logic. The derived meaning is based on a scalar implicature of exclusivity (“not both”), which eliminates the truth condition in which both disjuncts are true (see, e.g., Chierchia & McConnell-Ginet 2000; Gazdar 1979; McCawley 1981; Pelletier 1977).

The implicature of exclusivity arises because the disjunction word *or* forms a scale with the conjunction word *and*. The scale  $\langle or, and \rangle$  is constructed based on information strength, with *and* being stronger (more informative) than *or* (Horn 1972). As indicated in Table 1, the conjunctive statement *A and B* is true in just one circumstance, i.e., when both A and B are true. By contrast, the disjunctive statement *A or B* is true in three circumstances, i.e., not only when both A and B are true, but also when either A alone is true, or when B alone is true. In short, *A and B* is true in a subset of the circumstances that verify *A or B*. Therefore, the conjunctive statement *A and B* is stronger and logically entails the disjunctive statement *A or B*. This subset/superset relation of the truth conditions of *A and B* and *A or B* determines the information strength of *and* versus *or*, where the more informative (stronger) term on the scale is *and*, because *and* is true in a narrower range of circumstances than *or*.

The implicature of exclusivity becomes operational when the statement with *and* and the statement with *or* are both known by the speaker to be true in the conversational context. In this case, the Principle of Cooperation (Grice 1975, 1989) (submaxim of quantity) guides the speaker’s choice of which scalar term to use. The Principle of Cooperation entreats speakers to be as informative as possible, i.e., to select the stronger sentence, when a sentence with *and* and one with *or* are both true. In such circumstances, a cooperative speaker is supposed to avoid using a sentence with *or* because this would constitute a weaker statement than the speaker is prepared to make

TABLE 1  
Truth Tables for  $A \vee B$ ,  $A \wedge B$ ,  $\neg (A \vee B)$  and  $\neg (A \wedge B)$

A	B	$A \vee B$	$A \wedge B$	$\neg (A \vee B)$	$\neg (A \wedge B)$
T	T	T	T	F	F
F	T	T	F	F	T
T	F	T	F	F	T
F	F	F	F	T	T

Note.  $\neg$  is negation (NOT),  $\vee$  is disjunction (OR), and  $\wedge$  is conjunction (AND).

(i.e., one with *and*). Moreover, if the speaker uses *or*, the listener might contradict him/her by suggesting a replacement of the weaker term *or* with the stronger term *and*. That is, the listener may take the speaker's use of *or* to imply *not both*. In other circumstances, however, the speaker may not be confident that the statement with *and* is true, though the speaker may be confident in asserting the statement with *or*. In this case, the sentence with *or* makes the strongest statement the speaker is in a position to make. Upon hearing the speaker use the weaker statement with *or*, the listener assumes that the speaker was being cooperative and infers that the speaker was not in a position to use the stronger statement with *and*. Consequently, in these circumstances, the listener will also adopt the truth condition associated with the "derived" meaning of disjunction (i.e., exclusive-*or*), where the implicature of exclusivity is enforced.

The implicature account explains why adults' daily usage of disjunction, more often than not, conveys a meaning that is consistent with exclusive-*or*. Suppose that children's initial knowledge of disjunction is based on the input from adults, they would be expected to assign disjunction an exclusive-*or* interpretation. Exactly this conclusion has been reached in support of the usage-based account. Let us consider the evidence advanced in the study by Morris (2008), which is the most meticulous study to date on children's spontaneous production of disjunction. This study reviewed 240 transcriptions of audio taped exchanges between 40 English-speaking children (ages 2;00 to 5;00) and their parents taken from the CHILDES database, with 465 uses of *or* (out of 100,626 conversational turns). For children of different age ranges, *or*-utterances used for the circumstance in which one or the other disjunct or both were true accounted for less than 11% of the data, and this type of *or*-utterances only accounted for less than 17% of adults' total *or*-utterances. For about 75%–95% of the time, children and adults used sentences with *or* where only one disjunct (but not both) was true. Morris concluded that children's initial knowledge of disjunction is restricted to the nonlogical meaning of exclusive-*or*, similar to this informal use of disjunction by adults in natural language input.

However, the evidence adduced by Morris does not show that children were assigning disjunction to the meaning of exclusive-*or* rather than inclusive-*or*. This is because sentences with inclusive-*or* are also true when only one disjunct is true, as indicated in Table 1. So every utterance that was counted as evidence for exclusive-*or* was, in fact, equally valid evidence that the meaning of disjunction was inclusive-*or*—if this was children's initial (innate) interpretation. To show that the initial meaning children assign to disjunction is confined to exclusive-*or*, but not inclusive-*or*, then what must be shown is that they judge sentences with *or* to be *false* in the circumstance in which both of the disjuncts are true, since this is the only circumstance that distinguishes exclusive-*or* from inclusive-*or* in positive sentences (e.g., Crain, Gualmini & Meroni 2000; Noveck et al. 2002; see Paris 1973; Pelletier 1977).

From the view of logical nativism, the circumstance in which both of the disjuncts are true is the very circumstance one is expected to witness the determinant data for children's initial interpretation of inclusive-*or*, rather than exclusive-*or*. We have seen that scalar implicatures are theoretically linked to the conventional uses of *or* by adults. Experimental studies of adults have supported this linkage (e.g., Noveck et al. 2002). In contrast to adults, young children have not been found to derive scalar implicatures to the same extent that adults do until around school age (see, e.g., Chierchia et al. 2001; Guasti et al. 2005; Noveck 2001). Much has been investigated in the field of experimental pragmatics about this intriguing developmental pattern of children's computation of scalar implicatures as well as its implications for revealing the mechanisms underlying the generation of scalar implicatures (see Noveck & Reboul 2008 for a review). For the

purpose of logical nativism, the essential argument in the acquisition of the meanings of logical connectives is that children may initially associate disjunction with the meaning corresponding to its interpretation in classical logic, i.e., inclusive-*or*, even in circumstances in which adults' interpretation is governed by the scalar implicature of exclusivity (Crain 2008, 2012; Crain & Khlentzos 2008, 2010). One important component of the present study has sought to explore this possible mismatch between children versus adults in conditional statements, which to date hasn't been studied previously in child language.

Furthermore, human languages universally invoke inclusive-*or* for both children and adults in contexts where the implicature of exclusivity is not enforced. One way is to introduce specific linguistic contexts that reverse entailment relations of sentences with *or* and those with *and* (Chierchia 2004). Consider negative statement (1). Notice that (1) is true in one single circumstance, where Lydia didn't bring cake to the party *and* Lydia didn't bring ice cream to the party.

- (1) Lydia didn't bring cake **or** ice cream to the party.  
 $\Rightarrow$  Lydia didn't bring cake to the party and  
 Lydia didn't bring ice cream to the party.

However, if *or* is replaced by *and*, as in the sentence *Lydia didn't bring cake and ice-cream to the party*, it yields a statement that is true in a broader range of circumstances. Specifically, the statement with *and* is true in three circumstances: (i) where Lydia brought cake, but not ice cream, to the party; (ii) where Lydia brought ice cream, but not cake, to the party; and (iii) where Lydia didn't bring cake and she didn't bring ice cream to the party. Only the third of these truth conditions—the circumstance in which Lydia brought neither dessert—makes the sentence in (1) true. So the use of *or* in the scope of negation yields a more informative statement than the corresponding statement with *and*. This is also verified by the subset/superset relation of the truth conditions of  $\neg(A \vee B)$  and  $\neg(A \wedge B)$ , as given in Table 1. Consequently, the implicature of exclusivity that would otherwise arise in most positive linguistic contexts does not emerge in the scope of negation because retaining the literal inclusive-*or* interpretation results in a stronger statement.<sup>1</sup>

It is important to note, moreover, that natural language resembles classical logic in that the interpretive pattern in negative statement (1) is captured by one of the famous de Morgan's laws of propositional logic, as illustrated in (2). The schema in (2) states that the negation of the disjunction of two propositions is logically equivalent to a conjunction that is made up of the negation of each proposition. We refer to this phenomenon as the “conjunctive” entailment of disjunction under negation (e.g., Higginbotham, 1991).

- (2)  $\neg(A \vee B) \Rightarrow \neg A \wedge \neg B$

<sup>1</sup>Negative statements of the form  $\neg(A \vee B)$  offers another way to distinguish between inclusive-*or* and exclusive-*or*. As Jennings (2001) points out, if disjunction is exclusive-*or*, then statement (1) will be *true* if Lydia brought both cake and ice cream to the party. However, to our knowledge, no evidence has been reported in the literature demonstrating that children or adults make such critical judgments that are expected if disjunction is exclusive-*or*.



In classical logic, the inclusive-*or* interpretation of disjunction is the building block for this one of de Morgan's laws. In human languages, we can determine whether or not disjunction corresponds to inclusive-*or* by identifying linguistic structures that license the conjunctive entailment of disjunction and, thereby, sidestep the scalar implicature of exclusivity (Crain 2008, 2012).

## 2.2. Disjunction in the Antecedent Clause versus the Consequent Clause of Conditional Statements

Beyond negation, there is a more general class of linguistic contexts that licenses the conjunctive entailment of disjunction and in which a scalar implicature of exclusivity does not arise. This class of linguistic contexts is called "downward entailing contexts" (Crain 2008, 2012; see Chierchia 2004). By definition, downward entailing contexts license inferences from sets to their subsets (Ladusaw 1979). Example (3) shows that the antecedent clause of a conditional statement is downward entailing, validating inferences from the set-referring term *cake* to the subset-referring term *chocolate cake*.<sup>2</sup> By contrast, as illustrated in (4), the consequent clause of a conditional is not downward entailing because it does not validate inferences from sets to their subsets.

- (3) If a boy bought cake, then he got a plate.  
 $\Rightarrow$  If a boy bought chocolate cake, then he got a plate.
- (4) If a boy got a plate, then he bought cake.  
 $*\Rightarrow$  If a boy got a plate, then he bought chocolate cake.

Another diagnostic of downward entailing contexts is the interpretation of disjunction. Disjunction licenses a conjunctive entailment when it appears in the scope of a downward entailing expression (see e.g., Crain 2008; Partee, ter Meulen & Wall 1990). We illustrated this earlier with one downward entailing operator, negation. The antecedent clause of a conditional statement is also downward entailing. It follows that disjunction licenses a conjunctive entailment when it appears in the antecedent clause. Evidence in support of this is offered in (5).

- (5) If a boy bought cake **or** ice cream, then he got a plate.  
 $\Rightarrow$  if a boy bought cake, then he got a plate **and**  
 if a boy bought ice-cream, then he got a plate

Because negation and downward entailing contexts in general reverse entailment relations, disjunction is assigned its basic inclusive-*or* meaning when it appears in the scope of a downward entailing operator; no scalar implicatures are generated. Sentence (5) could be used, for example, to describe the situation in which if a boy bought both cake and ice cream, then he got a plate. This applies to both child language and adult language.

We saw that the consequent clause of conditional statements is not downward entailing. Therefore, disjunction does not license the conjunctive entailment when it appears in the consequent clause, and the implicature of exclusivity may arise in adult language. This is shown in example (6). According to classical logic, sentence (6) is true in three circumstances in which if a boy got a plate, then he bought cake alone, or ice cream alone, or both cake and ice cream. Since

<sup>2</sup>There are cases where conditional statements are not strictly downward entailing (see Heim 1984; Kadmon & Landman 1993; von Stechow 1999). We will set aside these cases for the purposes of the present article.



the sentence can have the full range of truth conditions associated with inclusive-*or*, we call this the “disjunctive” truth conditions of disjunction in nondownward entailing contexts.

- (6) If a boy got a plate, then he bought cake *or* ice cream.

As mentioned, in circumstances in which both (6) and its counterpart with *and*, i.e., *If a boy got a plate, then he bought cake and ice cream*, are true, a scalar implicature of “not both” is expected to become operational in adult language; thereby adults may assign disjunction the truth conditions that are associated with exclusive-*or*. Intuitively, sentence (6) seems inappropriate for adult speakers as a description of the situation in which if a boy got a plate, then he bought both cake and ice cream. But this intuition may not be pervasively shared among young children, who are more likely to endorse the basic meaning of inclusive-*or*, due to their insensitivity to scalar implicatures.

The observation that disjunction licenses a conjunctive entailment in the antecedent clause of conditional statements but not in the consequent clause has been found to hold in typologically different languages, so this has been advanced as a semantic universal (Crain 2008, 2012; Crain, Khlentzos & Thornton, 2010). When the English examples (5) and (6) are translated into Chinese or Japanese, for example, the corresponding statements manifest the same asymmetric truth conditions of disjunction in the two clauses of conditional statements. Examples (7) and (8) illustrate the truth conditions that are associated with the Mandarin disjunction word *huozhe*, when it appears in the two clauses of *ruguo*-conditionals.

- (7) *Ruguo xiaonanhai mai-le dangao huozhe bingjiling, ta jiu na-le diezi.*  
 if boy buy-Asp cake or ice-cream he then get-Asp plate  
 ‘If a boy bought cake *or* ice cream, then he got a plate.’ = conjunctive
- (8) *Ruguo xiaonanhai na-le diezi, ta jiu mai-le dangao huozhe bingjiling.*  
 if boy get-Asp plate he then buy-Asp cake or ice-cream  
 ‘If a boy got a plate, then he bought cake *or* ice cream.’ = disjunctive

From the perspective of classical logic, it is no accident that natural language disjunction licenses a conjunctive entailment in the antecedent clause but not in the consequent clause. This is because the truth condition of a conditional  $p \rightarrow q$  (‘if  $p$ , then  $q$ ’) is logically equivalent to  $\neg p \vee q$  (‘not  $p$ , or  $q$ ’). Notice that this hidden negation in the antecedent, but not in the consequent, is subject to one of de Morgan’s laws in (2), which generates the conjunctive entailment.<sup>3</sup> Thus, the different behaviors of disjunction in the antecedent clause versus the consequent clause are accounted for by whether or not de Morgan’s law applies in these two contexts.

The present study is designed to assess Mandarin-speaking children’s interpretation of disjunction in the antecedent clause versus the consequent clause of conditional statements. The purpose is to explore the contribution classical logic makes to the acquisition of the meanings of logical connectives, not only in circumstances in which both children’s and adults’ interpretations are guided by classical logic but also in circumstances in which children and adults may differ due to differences in their sensitivity to scalar implicatures.

<sup>3</sup>The truth conditions of disjunction in the consequent clause are “disjunctive.” To see why, notice that when disjunction appears in the consequent clause, as in *If A then (B or C)*, it is logically equivalent to *Not-A or (B or C)*. This, in turn, is logically equivalent to *(Not-A or B) or (Not-A or C)*. Hence, the following “disjunctive” inference is valid when disjunction appears in the consequent clause: *If A then (B or C)  $\Rightarrow$  If A then B or If A then C*.

### 3. PREDICTION: ACQUISITION OF DISJUNCTION IN CONDITIONAL STATEMENTS

According to logical nativism (Crain 2008, 2012; Crain & Khlentzos 2008, 2010), children would be expected to navigate easily through these complex linguistic structures involving the interaction between disjunction and conditionals by drawing upon an innate logical concept of the semantics of disjunction and conditionals, including the semantic universal that disjunction licenses a conjunctive entailment in the antecedent clause of conditional statements, but not in the consequent clause. On the other hand, the usage-based account explicitly rejects these hypotheses of logical nativism. Here is a representative quote from Morris (2008:68): “Children are not presumed to be endowed with error-free grammatical rules. . . . Instead, children form usage rules induced directly from instances they have heard.” On the usage-based account, Mandarin-speaking children’s linguistic behaviors in responding to conditionals with disjunction are solely determined by their linguistic experience. For the present study, it becomes critical to predict children’s linguistic behaviors, should their knowledge of disjunction and conditionals be guided by natural language input.

A survey of the CHILDES database was conducted to see how frequently Mandarin-speaking children encounter the disjunction word *huozhe* in *ruguo*-conditional statements. The search examined all of the transcripts from four Mandarin Chinese corpora in the CHILDES database (MacWhinney 2000): the Beijing and Context corpora (Tardif 1993, 1996) and the Zhou (1) and Zhou (2) corpora (Zhou 2002; Zhou & Li 2008). The search examined all files containing conversation between adult caregivers (most often the child’s mother or father) and individual child subjects between the ages of 1;02 and 6;00. These include 116,192 utterances by adults to 145 Mandarin-speaking children collected in naturalistic interactions or in semistructured parent–child play sessions. The CLAN program was used to identify the number of utterances containing the target words and to pick out the immediate context, i.e., four utterances before and after each of the target words.

The main finding was this: There was not a single instance of *huozhe* in *ruguo*-conditional statements in any of the adult input to the 145 children. A closer examination of individual connectives revealed only 16 adult utterances with *huozhe* and only 27 adult utterances with *ruguo*. The 16 adult utterances with *huozhe* generally indicated choices between alternatives (e.g., *Jiang waiyu gei mama ting huozhe lai ge feiwen ba* ‘Speak a foreign language to mum or give [me] a kiss’), or they presented mutual exclusive alternatives (e.g., *Shuo hao huozhe buhao* ‘Say good or not good’). This finding is compatible with the English input data cited in support of the usage-based account, which also suggested that English *or* was used to convey the core concept of “choice” (Morris 2008; see French & Nelson 1985). Because the dominant usage of disjunction in the adult input is overtly more consistent with exclusive-*or* rather than inclusive-*or*, on the usage-based account, children’s initial knowledge of disjunction would be restricted to the meaning of exclusive-*or* (Morris 2008; see French & Nelson 1985). As a result, young children may find it hard to assign the inclusive-*or* interpretation to disjunction; for example, it may be difficult for them to judge statements with *huozhe* as true in situations in which both disjuncts are true. Moreover, it may be even harder for them to assign the conjunctive entailment of disjunction in the antecedent clause of conditionals, which is based on the inclusive-*or* interpretation and which also evokes the generation of complicated entailment relations that are not readily attested in children’s natural language environment.

The transcriptions also seemed to lack any critical data revealing the different entailment properties of the two clauses of conditional statements. There were only 27 adult sentences containing *ruguo*, among which 10 were questions (e.g., *Ruguo guo shengdanjie, ni zui xiang dedao shenme liwu a?* ‘If it is Christmas, what gifts do you want the most?’), and 6 were one-clause fragments (e.g., *Ruguo bu hao wan . . .* ‘If it is not funny . . .’). Only 11 of the 27 adult sentences with *ruguo* contained both an antecedent clause and a consequent clause (e.g., *Zhege shihou ruguo bu dazhen, na xiaopengyou pipishu jiu bu yonggan le.* ‘At this time, if (she) doesn’t get the injection, then little Piggy Mouse is not brave’). But there is no evidence showing that only the antecedent clause (but not the consequent clause) is downward entailing. As a consequence, there are hardly any relevant data in the input to inform Mandarin-speaking children that disjunction licenses a conjunctive entailment in the antecedent clause of a *ruguo*-conditional statement, but not in the consequent clause.<sup>4</sup>

Could there be other evidence available, beyond the particular linguistic structures themselves, which informs children about the meanings of logical connectives? Recent usage-based theorists have suggested that children are capable of constructing abstract generalizations on the basis of “indirect” distributional evidence, by using general cognitive mechanisms (e.g., Gentner & Namy 2006; Elman 2009; Real & Christiansen 2004; Tomasello 2003). Following this line of reasoning, it could be supposed that language learners construct the formal representations of logical connectives through general cognitive skills such as analogical reasoning (Morris 2008; see Gentner & Namy 2006; Tomasello 2003). The idea is that children are able to make comparisons between utterances that contain similar lexicons, structures, and functions. In making these comparisons, children notice the commonalities that are needed for the subsequent generalizations. Still, a “critical mass” of such utterances would be required in order to enable children to accomplish the requisite analogical processing (Morris 2008; see Gentner & Namy 2006; Tomasello 2003). Thus, it becomes important to consider phenomena what the usage-based approach may regard as “analogous” to the target phenomenon. The immediate question is whether children may form the abstract representations through analogical learning via downward entailing contexts other than the antecedent clause (e.g., negative sentences, sentences with the universal quantifier *mei* ‘every,’ sentences with the temporal conjunction *zai . . . zhiqian* ‘before’). To explore this possibility, we looked more closely at the 16 adult utterances that contained the disjunction word *huozhe*. It turned out that these sentences with *huozhe* were all presented in nondownward entailing contexts. This means that children lack any evidence bearing on the interpretation of *huozhe* in any downward entailing contexts, not just in the antecedent clause of conditional statements.

Another solution is available to the usage-based account. Perhaps children utilize “indirect” cues to compute grammatical generalizations, when “direct” evidence of the very structures themselves is not in the input (e.g., Elman 2009; Real & Christiansen 2004). Much has been highlighted recently of the observation that statistical learning models can learn abstract generalizations (see, e.g., Romberg & Saffran 2010 for a review). For example, it has been shown that the distributional probabilities of the boundaries of nonsense syllables suffice for young children to segment “words” from the input (e.g., Lewis & Elman 2001; Real & Christiansen

<sup>4</sup>For further discussion about downward entailment as a “core” universal property that raises special challenges for the usage-based account, see e.g., Crain & Pietroski 2002; Crain, Gualmini & Pietroski 2005; Crain, Thornton & Khlentzos 2009; Crain, Khlentzos & Thornton 2010. See also Su, Zhou & Crain 2012 for a view from Mandarin Chinese.

2004; Saffran, Aslin & Newport 1996; but compare to Yang 2004). It is possible that, by adopting the same kind of statistical machinery, children might learn that linguistic expressions like Mandarin *renhe* or English *any* can appear in the antecedent clause of a conditional statement (e.g., *Ruguo xiaonanhai dian-le renhe dangao, ta jiu dedao-le diezi* ‘If a boy ordered any cake, then he got a plate’) but not in the consequent clause (e.g., *Ruguo xiaonanhai dedao-le diezi, ta jiu dian-le \*renhe dangao* ‘If a boy got a plate, then he ordered \*any cake’). That is, children may notice the distributional probabilities of these overt morphemes (e.g., Mandarin *renhe* or English *any*) in the input and to distinguish between grammatical and ungrammatical generalizations. However, what children learn about disjunction is not its distributional properties, but its interpretive properties. What children must learn is that disjunction generates different truth conditions, when the same lexical item *huozhe* appears in the antecedent clause versus the consequent clause. Even given the most optimistic assumptions about children’s ability to formulate generalizations via distributional regularities, the usage-based approach is hard-pressed to account for the acquisition of the asymmetric truth conditions of disjunction in the two clauses of conditional statements because the distinction is not based on explicit distributional patterns of disjunction but its implicit interpretative patterns. Without an innate knowledge of the semantic property of downward entailment, children could hardly cognize the different entailment properties of the antecedent clause versus the consequent clause as well as their subsequent consequences for the asymmetric truth conditions of disjunction in these two positions (Crain, Khlentzos & Thornton 2010; see Chierchia 2004).

To summarize, acquisition of disjunction in the antecedent clause versus the consequent clause provides an excellent testing ground for different theoretical accounts on the acquisition of the meanings of logical connectives. On the usage-based account, young children are anticipated to assign the nonlogical meaning of exclusive-*or* to disjunction, and they may easily err when encountering the unfamiliar logical uses of disjunction in conditional statements. By contrast, on the logical nativist account, young children across languages are expected to interpret disjunction as inclusive-*or* and to master the asymmetric truth conditions of disjunction in the two clauses of conditional statements, despite the observation that adults’ daily usage of disjunction is heavily obscured by the implicature of exclusivity and that there is hardly any evidence in natural language environment to inform them about the intriguing interaction between disjunction and conditionals. The present study attempts to adjudicate between these different acquisition scenarios. Before reporting the experiments, we review previous research on children’s knowledge of the meanings of disjunction and conditionals.

#### 4. PREVIOUS RESEARCH IN CHILD LANGUAGE

In the past two decades, evidence has been accumulated showing that young children acquiring typologically different languages know that disjunction is inclusive-*or*. The main evidence for this is the finding that children assign a conjunctive entailment to disjunction when it appears in the scope of a variety of downward entailing operators (see Crain 2008, 2012 for reviews).

We noted earlier that the conjunctive entailment was assigned to disjunction in negative sentences, following one of de Morgan’s laws of propositional logic:  $\neg (A \vee B) \Rightarrow \neg A \wedge \neg B$ . In a series of cross-linguistic studies, researchers have concluded that 3–5-year-old

children adhere to this one of de Morgan's laws in interpreting negative sentences with disjunction. This conclusion has been confirmed in studies of children acquiring English (Crain et al. 2002; Gualmini & Crain 2002), Japanese (Goro & Akiba 2004), and Mandarin Chinese (Jing, Crain & Hsu 2005). It is worth noting that when disjunction appears in simple negative sentences in English, adults follow de Morgan's law and assign disjunction a conjunctive entailment. In Japanese and in Mandarin, however, adult speakers interpret disjunction as taking scope of local negation, so the adult interpretation of disjunction for speakers of these languages does not fall under the purview of de Morgan's law (Crain 2012).<sup>5</sup> Nevertheless, children speaking all three languages were found to initially assign a conjunctive entailment to disjunction in simple negative sentences, in adherence to de Morgan's law. This difference between Japanese-speaking children and adults, and between Mandarin-speaking children and adults, is strong circumstantial evidence against the usage-based account of the acquisition of logical connectives (Crain, Goro & Thornton 2006).

The original study was conducted by Goro and Akida (2004). In a typical trial, a pig had eaten a carrot but not a green pepper, and the puppet uttered the sentence *Butasan-wa ninjin ka piiman-wo tabe-nakat-ta* 'The pig didn't eat the carrot or the pepper.' Japanese-speaking adults accepted this kind of test sentences 100% of the time, suggesting that they interpreted the target sentence as *The pig didn't eat the carrot or the pig didn't eat the pepper*. In contrast, the acceptance rate in Japanese-speaking children was only 25%. Children typically rejected the target sentence by saying 'The pig did eat one of the vegetables' or 'It was only one of the vegetables that the pig didn't eat.' This suggests that, different from adults, children interpreted disjunction as generating a conjunctive entailment, e.g., *The pig didn't eat the carrot and the pig didn't eat the pepper*. This pattern of results was replicated in Mandarin Chinese (Jing, Crain & Hsu 2005). Another set of recent studies by Notley et al. (2012) reported that English-speaking children and Mandarin-speaking children initially assigned disjunction a conjunctive entailment when it appeared in the scope of a temporal conjunction: English *before* and Mandarin *zai . . . zhiqian*. Again, interpretation in adult speakers of these languages differed from children, presumably due to a difference in logical scope. These mismatches between adult data and child data pose another challenge for the usage-based account.

Other evidence has been amassed from studies demonstrating children's knowledge of the conjunctive entailment of disjunction in structures that characterize adults' linguistic competence. To cite several examples, children have been found to be adultlike and assign a conjunctive entailment of disjunction (a) in the subject phrase of the universal quantifier *every* (Gualmini, Meroni & Crain 2003; Su & Crain 2013), (b) in the predicate phrase of the negated universal quantifier *not every* (Notley, Thornton & Crain 2012), (c) in the assertion of certain focus expressions such as *only* (Goro, Minai & Crain 2005; Jing, Crain & Hsu 2005), and (d) in the predicate phrase of the negative quantificational expressions *none* (Gualmini & Crain 2002) and *nobody* (Su, Zhou & Crain 2012). In view of the complexity of these linguistic structures, it seems unlikely that children could have acquired the relevant semantic knowledge from their linguistic experience,

<sup>5</sup>This one of de Morgan's laws applies only if negation takes scope over disjunction. When disjunction appears in simple negative sentences, languages are partitioned into two groups (Crain & Thornton 2013; Goro & Akiba 2004; Notley et al. 2012; Szabolcsi 2002). In languages like Hungarian, Japanese, Chinese, Russian, Serbo-Croatian, Slovak, and Polish, disjunction takes scope over local negation. In languages like English, German, French, Greek, Romanian, Bulgarian, and Korean, negation takes scope over disjunction.

but it is evident that children demonstrate adultlike competence of the complicated linguistic phenomena.

This conclusion is reinforced by the evidence that the same pattern of findings has been observed in typologically distinct languages. One series of studies has shown that both 3–5-year-old English-speaking and Mandarin-speaking children generated the conjunctive entailment of disjunction in the subject phrase of the universal quantifier, a downward entailing context, but not in the predicate phrase of the universal quantifier, which is nondownward entailing (Boster & Crain 1993; Gualmini, Meroni & Crain 2003; Su & Crain 2013; see Su, Zhou & Crain 2012). In a typical trial in the Mandarin study (Su & Crain 2013), two aliens who bought a car chose books, but not the two aliens who bought an airplane. Mandarin-speaking children rejected test sentences like *Mei-ge mai-le feiji huozhe xiaoqiche de waixingren dou xuanze-le shu* ‘Every alien who bought an airplane or a car chose a book’ in this situation 91% of the time. This indicates that they licensed the conjunctive entailment in the subject phrase of the Mandarin universal quantifier *mei*, e.g., *Every alien who bought an airplane chose a book and every alien who bought a car chose a book*. By contrast, when *huozhe* appeared in the predicate phrase of *mei*, the subjects didn’t request the conjunctive entailment. In a typical trial, two princesses who carried a dog stole a jewel and the other two princesses who carried a dog stole a ring. Children accepted test sentences like *Mei-ge dai-zhe gou de gongzhu dou tou-le baoshi huozhe jiezhi* ‘Every princess who carried a dog stole a jewel or a ring’ in this condition 95% of the time, suggesting that they assigned disjunctive truth conditions to disjunction, e.g., *Every princess who carried a dog stole either a jewel or a ring or (possibly both)*. Moreover, a search through the transcripts of adult input to children reveals that the relevant structures are not readily attested in children’s language environments (Su, Zhou & Crain 2012).

So far, these reviewed cross-linguistic studies indicated that child language generates similar entailments as those with disjunctive statements in classical logic, in favor of the view of logical nativism. In addition, recent developmental studies on scalar implicatures have also shed important insight into the acquisition of logical words, including logical connectives. For instance, several studies have investigated the roles scalar implicatures and entailment patterns play in children’s interpretation of disjunction (Chierchia et al. 2001, 2004; Gualmini et al. 2001; Su 2013). One representative study comes from Chierchia et al. (2001), which tested two different groups of 3–6-year-old English-speaking children on their interpretation of *or* in the two arguments of *every*. One group of children (and adults) was tested with sentences including *or* in the subject phrase of *every*, a downward entailing context. In a typical trial, every dwarf who chose both a banana and a strawberry received a jewel, and the puppet uttered the description *Every dwarf who chose a banana or a strawberry received a jewel*. Children were found to accept this type of test sentences 91.6% of the time, similar to the acceptance rate of 95.5% in adult controls. This suggests that both children and adults interpreted *or* inclusively, without computing scalar implicatures in downward entailing contexts (see also Chierchia et al. 2004; Gualmini et al. 2001; Su 2013; see Papafragou 2006). Another group of subjects was tested with sentences including *or* in the predicate phrase of *every*, a nondownward entailing context. In a typical trial in which every boy chose both a skateboard and a bike, no adults agreed with the puppet’s description *Every boy chose a skateboard or a bike*. In contrast to adults’ consistent rejection, children had a much higher acceptance rate of 50% for this type of test sentences. Apparently, in nondownward entailing contexts, children more frequently accepted inclusive-*or* interpretation than adults who were biased toward the exclusive-*or* interpretation (see also Chierchia et al. 2004; Gualmini



et al. 2001; Su 2013). These results comport with the findings of a number of child studies across a variety of scalar terms, including quantifiers (Barner, Brooks & Bale 2011; Guasti et al. 2005; Huang & Snedeker 2009; Katsos & Bishop 2011; Noveck 2001; Pouscoulous et al. 2007), modals (Noveck 2001), and aspectuals (Papafragou 2006; Papafragou & Musolino 2003). These studies demonstrate that preschool children do not spontaneously derive scalar implicatures to the same extent as adults do, possibly because that children have limited processing resources in reaching the derived meaning (e.g., Chierchia et al. 2001; Huang & Snedeker 2009). In this respect, young children appear to be more logical than adults, since they tend to retain the basic meanings in situations in which adults' linguistic analysis is influenced by the intrusion of scalar implicatures (Noveck 2001).

Directly relevant to the current investigation is a study by Gualmini, Crain & Meroni (2000). This study investigated the interpretation of *or* in the antecedent clause of conditional statements by a group of English-speaking children (aged 3;02–5;09; mean = 4;08). On a typical trial, the puppet produced sentences such as *If a giraffe or a penguin is on the stage, then I get a coin*. Following the puppet's pronouncement, the stage curtain was drawn back, and one of two possible outcomes was revealed. On one outcome, only one character (either the giraffe or the penguin) was on the stage. On the second outcome, both the giraffe and the penguin were on the stage. Then, the puppet asked the child subject "Do I get a coin?" The main findings were that children responded positively (*Yes*) 86% of the time to the first outcome, when there was just one character on the stage. More importantly, the same children responded *Yes* 98% of the time to the second outcome, when both characters were on the stage. If children have assigned the exclusive-*or* interpretation, presumably they would have rejected the puppet's pronouncement when both characters appeared on the stage. These findings, therefore, suggest that children assigned the inclusive-*or* interpretation to disjunction in the antecedent clause of conditional statements. In another condition, the puppet produced a conditional statement with conjunction (*and*), e.g., *If a giraffe and a penguin are on the stage, then I get a coin*. In the situation where only one character was on the stage, the child subjects responded *No* 76% of the time to the sentences with *and*, indicating that children did not mistake *or* as *and* when they assigned the inclusive-*or* interpretation to disjunction.

The study by Gualmini, Crain & Meroni (2000) provided evidence for English-speaking children's knowledge of inclusive-*or* in the antecedent clause of conditional statements. However, children's interpretation of disjunction in the consequent clause of conditional statements was not investigated. The consequent clause provides another context to tease apart the inclusive-*or* versus exclusive-*or* interpretations, thus presenting a further testing ground to adjudicate between the two models of the acquisition of the meanings of logical connectives. Moreover, as noted in Section 3, the different truth conditions of disjunction in the two clauses of conditional statements pose special challenges for the usage-based account, but this hasn't been directly investigated in child language.

Therefore, the present study attempts to fill in the gap in the literature by conducting a systematic research into Mandarin-speaking children's knowledge of the interaction between disjunction and conditionals. Three experiments are presented. Experiment 1 is designed to assess whether children and adults assign an inclusive-*or* or an exclusive-*or* interpretation to *huozhe* in both the antecedent clause and the consequent clause of *ruguo*-conditionals, i.e., in circumstances in which both disjuncts are true. Experiment 2 takes a closer look at children's understanding of the different truth conditions of disjunction in the two conditional clauses, i.e., whether disjunction licenses



a conjunctive entailment in the antecedent clause but not in the consequent clause. Experiment 3 serves as a control experiment for the first two experiments, the main goal of which is to test whether children make a distinction between disjunction and conjunction, a confusion of which has been taken as an alternative explanation for children's access to inclusive-*or* (e.g., Paris 1973).

## 5. EXPERIMENT 1

Experiment 1 examines whether children and adults assign an inclusive-*or* or an exclusive-*or* interpretation to *huozhe* when it appears in the antecedent clause and the consequent clause of *ruguo*-conditionals. Particular to our interests is the role scalar implicatures play in the interpretation of disjunction by children and by adults. We have seen that scalar implicatures do not arise in downward entailing contexts. One such context is the antecedent clause of conditional statements. Therefore, the logical nativist account establishes the experimental hypothesis that both Mandarin-speaking children and adults will assign the basic inclusive-*or* interpretation to disjunction in the antecedent clause of *ruguo*-conditionals. We have seen also that nondownward entailing contexts engender the operation of the scalar implicature of exclusivity in statements with disjunction, at least for adults; children have been found to be less sensitive to scalar implicatures than their adult counterparts. This leads us to the second experimental hypothesis, again based on the logical nativist account, namely that adults will invoke the implicature of exclusivity when disjunction appears in the consequent clause of *ruguo*-conditionals, whereas children will continue to assign the basic inclusive-*or* interpretation in the consequent clause, due to their insensitivity to scalar implicatures.

### 5.1. Design

Experiment 1 consisted of two sessions. The first session assessed the subjects' interpretation of *huozhe* in the antecedent clause of *ruguo*-conditionals, and the second session assessed their interpretation of *huozhe* in the consequent clause of *ruguo*-conditionals. Sentences (9) and (10) represent the sample test sentences that were used in these two sessions respectively. Both disjuncts were true in the nonlinguistic contexts. This made it possible to directly compare the inclusive-*or* versus exclusive-*or* interpretations assigned to disjunction in each clause.

- (9) *Ruguo milaoshu bianchu xiaotuzi huozhe xiaoxiong, ta jiu keyi dedao jiangpin.*  
 If Mickey Mouse conjure up rabbit or bear he then can get reward  
 'If Mickey Mouse conjures up a rabbit or a bear, then he can get a reward.'
- (10) *Ruguo xiaoxiang tiaoguo-le dashitou, ta jiu dedao-le lizi huozhe caomei.*  
 If elephant jump-ASP big stone he then get-ASP pear or strawberry  
 'If the elephant jumped over the big stone, then he got a pear or a strawberry.'

When disjunction appeared in the antecedent clause, the test sentence made a prediction about what would happen later in the story, as example (9) illustrates. By contrast, when disjunction appeared in the consequent clause, the test sentence made a description about what had already happened in the story, as example (10) illustrates. So, this pair of test sentences, which contained disjunction in different conditional clauses, also differed in the modes of presentation: in the

prediction mode versus the description mode. This change in experimental contexts across test conditions enabled us to measure the impact of scalar implicatures on subjects' inclusive-*or* versus exclusive-*or* interpretations of disjunction in both clauses of conditional statements. To see this, the antecedent clause and the consequent clause had already established a pair of linguistic contexts, differing in whether or not scalar implicatures are operational. However, we couldn't present sentences (9) and (10) using the same description mode and to directly test the consequences of scalar implicatures on subjects' inclusive-*or* versus exclusive-*or* interpretations. The major problem is that when disjunction appeared in the antecedent clause of conditional statements, we couldn't assess the subjects' exclusive-*or* interpretation (if this was the interpretation they assigned to disjunction) directly in description mode. To illustrate, imagine a situation in which Mickey Mouse had conjured up both a rabbit and a bear and then he got a reward. At this point, suppose the subjects heard the description *If Mickey Mouse conjured up a rabbit or a bear, then he got a reward*, i.e., when sentence (9) was presented in description mode. In this situation, the use of disjunction would make the antecedent clause true on the inclusive-*or* interpretation but false on the exclusive-*or* interpretation. However, making the antecedent false (i.e., if the subjects activated a scalar implicature and assigned an exclusive-*or* interpretation) became an infelicitous experimental situation for judgment of the truth value of the whole conditional sentence, due to pragmatic oddity (Grice 1975, 1989; Jackson 1987; Noveck et al. 1991).<sup>6</sup>

For the purpose of felicitously measuring subjects' different behaviors on the inclusive-*or* versus the exclusive-*or* interpretations, when disjunction appeared in the antecedent clause, we have adopted the design by Gualmini, Crain & Meroni (2000). In this design, the subjects were not required to judge the truth values of the whole conditional statements on the basis of the truth values of each conditional clause. Instead, the design takes advantage of the feature of the prediction mode, a situation of uncertainty, as well as the fact that when a conditional 'if *p*, then *q*' is true, the truth of the antecedent *p* would suffice to make the consequent *q* true. To illustrate, when sentence (9) *If Mickey Mouse conjures up a rabbit or a bear, then he can get a reward* was uttered as a prediction, the antecedent clause introduced a degree of uncertainty as to which particular outcome would take place, and the consequent clause integrated a reward for the fulfilled prediction. Therefore, a subject was free to select from the entire set of possible outcomes that came to mind, based on the puppet's prediction, and to decide whether or not to give a reward. For instance, if the final outcome turned out that Mickey Mouse conjured up both a rabbit and a bear, then on the inclusive-*or* interpretation (which made the antecedent clause true), Mickey Mouse was supposed to receive a reward; otherwise, Mickey Mouse may not receive a reward on the exclusive-*or* interpretation (which made the antecedent clause false).<sup>7</sup> It is important to note that both the antecedent clause (a downward

<sup>6</sup>It is well documented that when required to judge a conditional statement with a false antecedent (which is logically true, despite the truth value of the consequent), subjects often gave a negative response of "false," or replied with "can't tell" when this kind of indeterminate response option was available (e.g., Braine & Romain 1983; O'Brien 1987). This is because when the antecedent is false, the subjects are required to judge the whole conditional sentence based on an assertion that is not relevant to the content of the consequent, which violates the Principle of Cooperation (Grice 1975, 1989; Jackson 1987; Noveck et al. 1991).

<sup>7</sup>From the view of logic, a conditional is true when its antecedent is false (no matter whether the consequent is true or false). It follows that on the exclusive-*or* interpretation (which made the antecedent false), sentence (9) remained true in both the situations in which Mickey Mouse received a reward (which made the consequent true) and when he didn't receive a reward (which made the consequent false). However, in our study, when the antecedent was false, almost all

entailing context) and the prediction mode (a situation of uncertainty)<sup>8</sup> are situations in which the derivation of scalar implicatures is not encouraged, thus making the inclusive-*or* interpretation felicitous.

For comparison, consider sentence (10) *If the elephant jumped over the big stone, then he got a pear or a strawberry*. This sentence contained disjunction in the consequent clause (a nondownward entailing context), and it was presented in description mode (a situation of certainty). In combination, these experimental manipulations (both the linguistic condition and the experimental context) were designed to facilitate the computation of a scalar implicature, if that computation was available to a subject. When both of the disjuncts were true in the context (e.g., the elephant got both a pear and a strawberry), adult subjects were expected to invoke a scalar implicature. If so, adult subjects should reject (10) on the grounds that the corresponding statement with *and* would have been more appropriate, i.e., by assigning disjunction an exclusive-*or* interpretation. However, young children have been proven to be less sensitive to scalar implicatures, so children were expected to accept sentences with disjunction in the consequent clause on the basis of inclusive-*or* interpretation. Importantly, we cannot change (10) into *If the elephant jumps over the big stone, then he can get a pear or a strawberry*, and to present it in the prediction mode. As noted, scalar implicatures don't arise in situations of uncertainty, including the prediction mode. Keeping the two sentences (9) and (10) consistent in prediction mode would then eliminate the influence of scalar implicatures on the subjects' interpretation of disjunction in both the antecedent clause and the consequent clause.

Proceeding with these analyses, we contend that sentences like (9) and (10) provided appropriate test stimuli that allowed us to measure the role scalar implicatures play in children's and adults' interpretation of disjunction (i.e., inclusive-*or* or exclusive-*or*) in the two conditional clauses. It becomes interesting to see how children and adults responded to these test sentences.

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the 32 child subjects in the final sample (98% of the time) and the 28 adult subjects (97% of the time) decided not to reward the characters. There were 4 children who always decided to reward the characters following all of the puppet's predictions, but their data were eliminated from the final analysis for two reasons. First, for the purpose of the present study, we need to distinguish between the subjects' interpretations of inclusive-*or* versus exclusive-*or* based on their observable behaviors. It becomes ideal if the subjects could make a distinction in their judgments of the truth or falsity of the antecedent clause, by providing positive or negative responses. Second, we were not sure about the reasons behind children's consistently affirmative replies (Crain & Thornton 1998).

<sup>8</sup>Scalar implicatures become operational only when the listener knows that the speaker has the accurate knowledge of the information strength of an alternative set of scalar expressions being used in the conversational context, where the speaker is supposed to choose the most informative statement. In situations of uncertainty, e.g., when *or* appears in a prediction or a bet or other future events, the listener knows that the speaker does not have an accurate knowledge about the situations being described, and the speaker is not supposed to know the truth values of alternative expressions containing scalar terms like *or* and *and*. Consequently, the speaker is not supposed to compare their information strength or to select the most informative sentence. In this case, the speaker's choice of *or* doesn't implicate the denial of the alternative expression, i.e., '*not both A and B*.' In this way, situations of uncertainty discourage the triggering of scalar implicatures and enable the interpretation of scalar terms like *or* to follow their basic meanings such as inclusive-*or* (Chierchia et al. 1998; Crain, Gualmini & Meroni 2000; see Horn 1972, 1989).

## 5.2. Session 1

### 5.2.1. Procedures

Following Gualmini, Crain & Meroni (2000), Session 1 employed a variant of the Truth Value Judgment task (Crain & Thornton 1998). The experiment was set up as a game, rather than composed of individual stories as in the traditional Truth Value Judgment task. Two experimenters were involved. One experimenter manipulated a puppet. The other experimenter introduced the game to the child and to the puppet, using cartoon characters and toy props. In this game, the characters participated in a magic competition by conjuring up objects, to win the prizes that were held by the child subject. The puppet's role was to instruct each of the characters about what s/he was supposed to conjure up, so that s/he could win the prizes. The child's task was to decide about whether or not to reward the characters, based on the puppet's instructions and the subsequent outcomes.

The child subjects were first introduced to the puppet in groups in a quiet room, away from the classroom and knew that the puppet could say something right or wrong. Then they were tested individually. Each child was familiarized with the structure of the game using four warm-up sentences. The warm-up sentences were conditional statements without disjunction, e.g., *Ruguo mini bianchu shuijingqiu, ta jiu keyi dedao jiangpin* 'If Minney conjures up a crystal ball, then she can get a reward.' The antecedent clause was made true for two of the warm-up sentences (e.g., Minney conjured up a crystal ball) and false for the other two (e.g., Minney conjured up a flower). As the experimental criteria, children who consistently rewarded the characters (i.e., by always giving affirmative replies to the test stimuli) would not participate further in the main session (Crain & Thornton 1998; see Footnote 7). The adult subjects were tested in groups by the same two experimenters and were instructed to write down their answers about whether or not to reward the cartoon characters.

### 5.2.2. Participants

Thirty-six monolingual Mandarin-speaking children from the Blue Sky Art Kindergarten in Changsha, China, participated in Session 1. Four children consistently rewarded the cartoon characters with prizes during the warm-up phase of the experiment and did not participate in the main session. This left a total of 32 children (aged 2;06–5;00, mean = 3; 09). In addition, 28 adult native Mandarin speakers were tested as controls. All these adult subjects were college students or recent graduates from universities in Changsha.

### 5.2.3. Materials

In the main session, the subjects were tested with a total of 12 conditional statements with the same structure as in (9), with *huozhe* appearing in the antecedent clause of *ruguo*-conditionals, at a random order. Below is a typical trial corresponding to test sentence (9) *Ruguo milaoshu bianchu xiaotuzi huozhe xiaoxiong, ta jiu keyi dedao jiangpin* 'If Mickey Mouse conjures up a rabbit or a bear, then he can get a reward.'

Experimenter: This is a magic game. Here we have Mickey Mouse to compete. He could do the conjuring tricks using his magic box.

Puppet: If Mickey Mouse conjures up a rabbit or a bear, then he can get a reward.  
*The experimenter opens Mickey Mouse's magic box, so the child can see what is inside.*

Puppet: Can Mickey Mouse get a reward?

The 12 conditional statements can be divided into 4 test sentences and 8 control sentences based on the final outcomes. The four test sentences were presented in which both disjuncts were true (i.e., in the TT condition, e.g., Mickey Mouse conjured up both a rabbit and a bear), aiming to tease apart the subjects' inclusive-*or* versus exclusive-*or* interpretations in the antecedent clause. The subjects would be expected to provide an affirmative reply on the inclusive-*or* interpretation and to reward the characters with prizes, but they may refrain from rewarding the characters on the exclusive-*or* interpretation. For the 8 control sentences, 4 were presented with one of the disjuncts being true (i.e., in the TF/FT condition, e.g., Mickey Mouse conjured up either a rabbit or a bear, but not both), in which two were true because of the first disjunct and the other two were true because of the second disjunct. The other 4 control sentences were presented in which none of the disjuncts were true (i.e., in the FF condition, e.g., Mickey Mouse conjured up a stone). These control sentences were included to verify that the subjects had access to the full range of truth conditions of inclusive-*or*. If so, they would be expected to provide affirmative replies to the TF/FT condition but negative replies to the FF condition. Moreover, the TF/FT condition was designed to ensure that the child subjects didn't mistake the disjunction word *huozhe* for the conjunction word *he*. If they did, then they would reject the control sentences in this condition.

#### 5.2.4. Results and Discussion

In response to the test sentences in the TT condition, children consistently rewarded the cartoon characters (99% affirmative responses) and adults made affirmative responses 87% of the time. There was a statistically significant difference between groups ( $Z = -2.77$ ,  $p = 0.006$ ). In response to the control sentences in the TF/FT condition, children correctly replied *Yes* 89% of the time, and adults 95% of the time. There were no significant differences between groups ( $Z = -1.13$ ,  $p = 0.26$ ). Finally, children rejected the control sentences in the FF condition 98% of the time and adults 97% of the time.

The findings resemble those reported in the study of English-speaking children by Gualmini, Crain & Meroni (2000), though the Mandarin-speaking children in the present study were younger than the child subjects in the Gualmini et al. study. The data provide further evidence that children interpreted disjunction as inclusive-*or* when it appeared in the antecedent clause of *ruguo*-conditionals. Adults were also found to assign an inclusive-*or* interpretation to disjunction in the antecedent clause (see also Noveck et al. 2002). But adults assigned an exclusive-*or* interpretation significantly more often than children did, presumably because of residual effect of a scalar implicature, which was unexpectedly applied in a downward entailing linguistic context (i.e., in the antecedent clause of conditionals), and in a situation of uncertainty (i.e., in prediction mode). Finally, children's high rate of acceptance of the control sentences in the TF/FT condition indicated that the child subjects did not mistake the disjunction word *huozhe* for the conjunction word *he* in the antecedent clause.

### 5.3. Session 2

#### 5.3.1. Procedures

Session 2 adopted the description mode of the Truth Value Judgment task (Crain & Thornton 1998). Different from the prediction mode, test sentences presented in the description mode were used to describe events that had already taken place, rather than as predictions about what would happen next. The task was conducted by two experimenters. The first experimenter acted out stories in front of individual child subject using props and toys. The second experimenter played the role of a puppet who watched the stories alongside the child. At the end of each story, the puppet produced a sentence that purported to accurately describe what happened in the story. The child's task was to judge whether the puppet's statement was right or wrong (i.e., true or false) and to reward the puppet with "ice cream" when it was right and with "a red pepper" when it was wrong. Moreover, the child was required to provide explanations whenever the puppet was wrong. To familiarize the child with the task, each subject was introduced with a warm-up session with four simple positive sentences (e.g., *Shizi zhaodao-le xiaowugui* 'The lion found the turtle'). Two of these warm-up sentences were designed to elicit *Yes* responses, and the other two were designed to elicit *No* responses. Only children who answered correctly for both the true and false sentences in the warm-up session were invited to participate in the main session. The adult controls were tested in groups and were instructed to indicate in writing whether the puppet was right or wrong and to provide explanations on every trial where the puppet had made an inaccurate statement.

#### 5.3.2. Participants

Participants included the same 32 child subjects who participated in Session 1 as well as the same 28 adults. All the 32 children answered the warm-up sentences correctly and were invited to participate in the main session.

#### 5.3.3. Materials

Each child subject was presented with four test stories. The following represents a typical story corresponding to test sentence (10), with *huozhe* appearing in the consequent clause of *ruguo*-conditionals: *Ruguo xiaoxiang tiaoguo-le dashitou, ta jiu dedao-le lizi huozhe caomei* 'If the elephant jumped over the big stone, then he got a pear or a strawberry.'

In this story, three elephants participated in a jumping game. A little boy promised to reward those elephants that could jump over hurdles with fruits. The first elephant jumped over a big stone, the second elephant jumped over a log, and the third elephant jumped over a fence. Finally, the little boy rewarded the first elephant that jumped over the big stone with both a pear and a strawberry. He rewarded a strawberry to the second elephant that jumped over the log. The third elephant that jumped over the fence received an apple.

At the end of the story, the puppet described what it thought had happened in the story. On each trial, the puppet uttered one test sentence, one control sentence, and one filler sentence. These were produced in random order, yielding a total of four test sentences, four control sentences,

and four filler sentences. The test sentences (e.g., *Ruguo xiaoxiang tiaoguo-le dashitou, ta jiu dedao-le lizi huozhe caomei* ‘If the elephant jumped over the big stone, then he got a pear or a strawberry.’) were descriptions of situations which made both disjuncts true (i.e., in the TT condition, the elephant got both a pear and a strawberry). The test sentences were designed to be judged correct only if a subject assigned an inclusive-*or* interpretation to disjunction, whereas they were pragmatically infelicitous for subjects who invoked a scalar implicature of exclusivity. We expected more negative responses from adult controls but fewer negative responses from the child subjects.<sup>9</sup> The control sentences had the same structure as the test sentences (e.g., *Ruguo xiaoxiang tiaoguo-le mutou, ta jiu dedao-le pingguo huozhe lizi* ‘If the elephant jumped over the log, then he got an apple or a pear’) but were presented in situations in which neither of the disjuncts was true (i.e., in the FF condition, e.g., the elephant got a strawberry). The control sentences were designed to evoke a *No* response and were included to verify that the subjects had no difficulties in rejecting false sentences that had the same level of complexity as the test sentences (Crain & Thornton 1998). Finally, filler sentences were included (e.g., *Ruguo xiaoxiang tiaoguo-le langan, ta jiu dedao-le caomei* ‘If the elephant jumped over the fence, then he got a strawberry’), to verify that subjects had no problem with judging the truth or falsity of conditional statements without disjunction. Two of the filler sentences were false and two were true.<sup>10</sup>

#### 5.3.4. Results and Discussion

The main finding was that children and adults produced different patterns of responses to test sentences in the TT condition. The acceptance rate was 91% for children versus 21% for adults ( $Z = -5.71, p < 0.0001$ ). To justify their rejections for sentences like (10), adults usually commented that the stronger conjunctive term *he* ‘and’ should have been used instead of *huozhe*. This indicated that adults’ rejections were the result of the scalar implicature of exclusivity “not both.” In contrast to adults, young children were not as sensitive to the influence of the scalar implicature, and they accepted the test sentences. Children’s affirmative responses were, therefore, circumstantial evidence that they assigned a logical inclusive-*or* interpretation to *huozhe* in a nondownward entailing context (i.e., in the consequent clause of conditional statements) and in a situation of certainty (i.e., in description mode).

Besides, children correctly rejected the (false) control sentences (i.e., in the FF condition) 90% of the time, and they produced correct responses to the filler sentences 93% of the time. Adults correctly responded to the control sentences and to the filler sentences 100% of the time. This

<sup>9</sup>Of course, if children interpreted the disjunction word *huozhe* to mean the conjunction word *he*, then they would also be expected to accept the test sentences in the TT condition. This possibility is dealt with in Experiment 3.

<sup>10</sup>We did not include the TF/FT condition in Session 2 because this would make the sentences infelicitous in the description mode. Specifically, the inference from *A* alone or *B* alone to a disjunctive statement (*A or B*) makes the sentence an instance of Weakening (a.k.a. Disjunction Introduction). It is well known that language users find instances of Weakening to be pragmatically odd when describing past events (Grice 1975; Horn 1989). For example, in a situation in which the elephant that jumped over the fence received an apple, it is pragmatically odd to use the description *If the elephant jumped over the fence, then he got a pear or an apple*. The pragmatic infelicity of Weakening is circumvented in situations of uncertainty, such as when describing future events in prediction mode (for further discussion, see Crain 2012; Crain & Khlentzos 2008, 2010). In this study, we tested the TF/FT condition in the antecedent clause in Session 1 and again in the consequent clause in Experiment 3; both were presented in prediction mode, thus making the TF/FT condition felicitous for testing.



suggests that children’s overwhelming affirmative replies to the test sentences were not resulting from a confusion of the experimental task or an uncertainty about the complex test sentences; rather this must be a true reflection of their linguistic knowledge.

The main result that deserves comment is the contrast between the patterns of logical responses by the two groups to the test sentences in the TT condition across the two sessions of Experiment 1. To investigate the extent to which scalar implicatures affected subjects’ logical interpretation of disjunction in the TT condition, the data from Session 1 and Session 2 were analyzed using a Generalized Linear Mixed Model (GLMM) assuming a binomial family distribution. A GLMM were chosen because of its advantage over traditional ANOVAs, which can yield spurious significant results when applied to categorical variables (Jaeger 2008). Data from the 60 participants were analyzed using the following fixed factors: “context” (antecedent/prediction versus consequent/description) and “group” (children versus adults). The random factors were subjects and items. The analysis revealed a significant main effect of context ( $p < .05$ ), a significant main effect of group ( $p < .05$ ), and a significant context by group interaction ( $p < .01$ ). This suggests that contextual factors have different effects on children’s versus adults’ logical interpretations of disjunction. We confirmed the developmental effects revealed by the GLMM using a Pearson’s chi-square test of contingencies. This analysis compared the proportion of children and adults who provided logical responses (i.e., replied with *Yes* on the inclusive-*or* interpretation) to the test sentences three times or more for both contexts. The chi-square test was highly significant, as 91% of the child subjects (29 out of 32) replied *Yes* three times or more when disjunction appeared in both the antecedent clause and the consequent clause; whereas only 18% of the adult subjects (5 out of 28) produced the same pattern of responses ( $\chi^2 = 32.2$  ( $df = 1$ ,  $n = 60$ ),  $p < .0001$ ). Table 2 presents a summary of the descriptive data averaged across the two test contexts by groups.

The findings indicated the different influences of scalar implicatures on children’s and adults’ interpretations of disjunction. In particular, adults favored the inclusive-*or* interpretation to *huozhe* in Session 1, in contexts in which scalar implicatures were not expected to arise (i.e., the antecedent clause and the prediction mode). Nevertheless, the proportion of acceptance was slightly lower for adults than it was for children. However, adults assigned far fewer inclusive-*or* interpretations to disjunction in Session 2, in contexts in which scalar implicatures were facilitated

TABLE 2  
Percentage of Children’s and Adults’ Logical Responses to the Test Sentences in Experiment 1

<i>Sentence type</i>	<i>Logical response</i>	<i>Children (N = 32)</i>	<i>Adults (N = 28)</i>
Disjunction in the Antecedent Clause e.g., <i>If Mickey Mouse conjures up a rabbit or a bear, then he can get a reward.</i>	YES	99	87
Disjunction in the Consequent Clause e.g., <i>If the elephant jumped over the big stone, then he got a pear or a strawberry.</i>	YES	91	21

(i.e., the consequent clause and the description mode). By contrast, 2–5-year-old Mandarin-speaking children adhered to the inclusive-*or* interpretation, even when *huozhe* appeared in the consequent clause. Children's responses, in contrast to those of adults, were not influenced by scalar implicatures. Therefore, children persistently assigned the basic inclusive-*or* interpretation to disjunction in both the antecedent clause and the consequent clause of conditional statements, as in classical logic.

## 6. EXPERIMENT 2

Experiment 2 evaluates children's knowledge of a putative semantic universal—that disjunction licenses a conjunctive entailment in the antecedent clause of conditional statements but not in the consequent clause. As we saw in Experiment 1, children initially assigned an inclusive-*or* interpretation to disjunction in the antecedent clause and the consequent clause, producing affirmative responses in the TT condition in both contexts. Experiment 2 was designed to test whether children detect the different truth conditions of disjunction in the two conditional clauses in different circumstances. In this way, we also utilize children's interpretation of disjunction as a yardstick to measure their knowledge of the different entailment properties of the antecedent clause versus the consequent clause. Importantly, all of the test sentences in Experiment 2 were presented in prediction mode, a situation of uncertainty in which scalar implicatures are not operational. This enables us to gain a more accurate picture of the interpretation of logical connectives by both children and adults, without the intrusion of scalar implicatures. Based on the logical nativist account, the experimental hypothesis is that both children and adults would be expected to access the different truth conditions of disjunction in the two clauses of conditional statements: They will assign a conjunctive entailment to disjunction when it appears in the antecedent clause but will assign the disjunctive truth conditions to disjunction when it appears in the consequent clause.

### 6.1. Procedures

Experiment 2 adopted the prediction mode of the Truth Value Judgment task (Chierchia et al. 1998). Two experimenters were involved, with the first experimenter acting out stories in front of the child subject using props and toys and the second experimenter playing the role of a puppet. In the middle of the story, the puppet produced a sentence that purported to predict what would happen in the remainder of the story. Then the story continued, and the puppet repeated the earlier prediction after the actual outcome had been revealed. The child's task was to judge whether or not the puppet's prediction turned out to be right or wrong, based on the final outcome, and to reward the puppet with "ice cream" when it was right and with "a red pepper" when it was wrong. When a child indicated that the puppet's prediction was wrong, the child was requested to explain to the puppet what really happened in the story. The explanation children produced was used in the subsequent data analysis to ensure that the child understood the story and produced a legitimate reason for rejecting the puppet's statement.

The child subjects were first introduced to the task in groups in a quiet room away from the classroom and knew that the puppet could say something right or wrong. Then children were

tested individually by the two experimenters. Each child witnessed one warm-up session that contained four sentences (two true and two false). All of them were simple positive sentences with future tense (e.g., *Xiaoxiong hui shen chu naodai* ‘The bear will stretch out his head’). If children answered all of the warm-up sentences correctly and produced appropriate justifications for their *No* responses, they were invited to participate in the two main sessions. Adult controls were tested by the first experimenter in one session that combined all the test sentences. These adult subjects were also instructed to indicate whether the puppet was right or wrong by writing down their answers. Whenever the adult subjects judged the puppet to be wrong, they were asked to provide justifications.

## 6.2. Participants

Forty-one monolingual Mandarin-speaking children participated in the study. The children were recruited at the Blue Sky Art Kindergarten in Changsha, China. Two children consistently replied *Yes* to the warm-up sentences and did not participate further in the main sessions. This left 39 children aged 3;11–5;05, with a mean age of 4;11. Fifteen adult native Mandarin speakers served as a control group. All these adult subjects were Chinese international students at Macquarie University in Sydney, Australia. None of these child or adult subjects participated in Experiment 1.

## 6.3. Materials

In the two main sessions, each child subject encountered eight test sentences, four of which containing *huozhe* in the antecedent clause and four containing *huozhe* in the consequent clause. For each session, the first two test trials contained sentences with *huozhe* in the antecedent clause, and the remaining two contained sentences with *huozhe* in the consequent clause. The stories were designed to make test sentences false when *huozhe* appeared in the antecedent clause but true when it appeared in the consequent clause. This was accomplished by satisfying one of the disjunctive truth conditions associated with disjunction but not the truth conditions corresponding to the conjunctive entailment of disjunction. To illustrate, the following represents one of the four stories in which *huozhe* appeared in the antecedent clause.

This story is about five ponies that helped a duck to move food to his new house. The duck said to the ponies, “I need to move these sausages, corns, and cake to my new house. Could you please help me?” The ponies agreed to help. The youngest pony with least strength moved the small cake. Two older and stronger ponies moved two sausages. Two biggest and strongest ponies moved two heavy corns. The duck said, “Well done! I should reward you for your generous help.” He brought out a lot of prizes, which included four gold coins, four purple shells, a pink star, and a flower ball. Now, how would the duck reward the ponies?

The puppet then made predictions about the prizes that the ponies could receive from the duck. The puppet’s first prediction was a filler sentence *Ruguo xiaoma yunzou dangao, ta jiu hui dedao zhuzi* ‘If a pony moves a cake, then he will get a marble.’ This was a simple conditional sentence referring to a specific character, i.e., the pony that moved the cake. Then the story continued. In the present story, the pony that moved the cake received a pink star, thus falsifying the puppet’s

prediction. The filler sentences were designed to maintain the child subjects' attention and to evoke an equal number of *Yes* and *No* responses. After the child judged the filler sentence, the puppet predicted what prizes the other ponies would get, using test sentence (11).

- (11) Ruguo xiaoma yunzou yumi huozhe huotuichang, ta jiu hui dedao jinbi.  
 if pony move corn or sausage he then will get gold coin  
 'If a pony moves a corn or a sausage, then he will get a gold coin.'

What happened next was that the two ponies that moved corns received gold coins. The two ponies that moved sausages didn't receive gold coins. Instead, the duck rewarded them with purple shells because the sausages they moved were smaller than corns. At this point, the puppet repeated test sentence (11) to remind the subject about her prediction and the subject was required to judge the truth or falsity of the test sentence.

The test sentence received a different truth value depending on whether or not children assigned the conjunctive entailment to *huozhe*. If children knew that the antecedent clause licensed the conjunctive entailment, they should interpret (11) as *if a pony moves a corn, then he will get a gold coin and if a pony moves a sausage, then he will get a gold coin*. Consequently, they should reject the test sentence on the grounds that the two ponies that moved sausages got purple shells.<sup>11</sup> However, if children did not generate the conjunctive entailment, then they may accept (11). This is possible if they misused the "disjunctive" inference pattern applicable to disjunction when it appeared in the consequent clause (see Footnote 3), as in *if a pony moves a corn, then he will get a gold coin or if a pony moves a sausage, then he will get a gold coin*. This reading made the test sentence true in the context because the ponies that moved corns got gold coins.

The remaining four stories assessed whether or not children allowed disjunctive truth conditions of disjunction when it appeared in the consequent clause. To illustrate, here is a typical story.

This story is about one dog, one peacock, and four rabbits that went to Minney's house to play a game called "finding jewels." Minney prepared different kinds of prizes, which included six balls, six butterflies, and six stars, to reward those jewel-finders. Finally, Minney's friends all succeeded. Minney said, "Good job! Now I will reward you with some prizes."

At this point, the puppet first predicted the prizes that the dog or the peacock could get by using two filler sentences (one true and one false), e.g., *Ruguo xiaogou zhaodao baoshi, ta jiu hui dedao xiaoqi* 'If the dog finds a jewel, then he will get a ball.' The subjects then judged the truth or falsity of the filler sentences on the basis of the subsequent outcomes. Following this, the puppet predicted about what the other four rabbits would receive, using test sentence (12).

- (12) Ruguo xiaotuzi zhaodao baoshi, ta jiu hui dedao xiaoqi huozhe xingxing  
 if rabbit find jewel she then will get ball or star  
 'If a rabbit finds a jewel, then she will get a ball or a star.'

What happened was that Minney rewarded two rabbits with balls, and she rewarded the other two rabbits with stars. Note that the story ended with every rabbit possessing one of the two

<sup>11</sup> An additional precaution was taken to remove a possible order effect. For half of the test sentences, the sentences were false in virtue of the first disjunct, and for the other half, the test sentences were false because of the second disjunct.

objects mentioned in the test sentence, but no rabbits possessed both objects. That is, the scenario made only one of the disjuncts true, but not both.

Children were expected to accept sentence (12) only if they assigned disjunctive truth conditions to *huozhe*, as in *If a rabbit finds a jewel, then she will get a ball or a star or possibly both*. If children did not distinguish the interpretation of disjunction in the antecedent clause versus the consequent clause, then they were expected to reject (12). This could happen, for example, if children analyzed both conditional clauses to be downward entailing, thereby licensing a conjunctive entailment of disjunction in both positions. If so, children's interpretation of (12) would require every rabbit who found a jewel to have received both a ball and a star, contrary to fact.

In addition to the eight test sentences, there were four control sentences (one true and one false in each session). The control sentences were similar in structure to the filler sentences but were presented with multiple characters. These sentences were included to ensure that children could process conditional statements without disjunction as descriptions of complex situations. In a typical control trial, four frogs picked flowers and one frog picked a feather for Tiger. The puppet predicted the prizes those frogs would receive, using the control sentence *Ruguo xiaqingwa zhaidao xiaohua, ta jiu hui dedao zibeike* 'If a frog picks a flower, then she will get a purple shell.' There were two possible outcomes. One was a false outcome in which two of the frogs that picked flowers received purple shells and two received butterflies. The other outcome was a true outcome, where all four of the frogs that picked flowers received purple shells. Each control sentence was preceded by a filler sentence referring to a specific character, e.g., *Ruguo xiaqingwa zhaidao yumao, ta jiu hui dedao baoshi* 'If a frog picks a feather, then she will get a jewel.' Finally, there were four filler trials. These were simple positive sentences with future tense (one true and one false in each session).

#### 6.4. Results and Discussion

As the experimental criteria, the data from children who failed to respond correctly to the filler sentences or control sentences in the main sessions were excluded from the final data analysis. All subjects responded correctly to the filler sentences. However, 9 child subjects incorrectly accepted the false control sentences, so their responses to the test sentences were excluded from the data analysis. The final sample included 30 children between the ages of 3;11 and 5;11, with a mean age of 4;11.

This experiment asked whether children assigned different truth conditions to *huozhe* when it appeared in the two clauses of *ruguo*-conditionals. If so, children were expected to reject the test sentences when *huozhe* appeared in the antecedent clause but to accept them when *huozhe* was used in the consequent clause. The results confirmed the experimental hypothesis. Specifically, when *huozhe* was used in the antecedent clause, children responded *Yes* only 3% of the time. By contrast, when *huozhe* was used in the consequent clause, children produced *Yes* responses 91% of the time ( $Z = -4.97, p < .0001$ ). Moreover, when *huozhe* was in the antecedent clause, children justified their negative judgments for the right reasons. For example, 20 children consistently justified their replies with *No* to (11) by pointing out that the two ponies that moved sausages received purple shells but not gold coins. The other 10 children typically justified their judgments by commenting that the puppet was right because the two ponies that moved corns did receive gold coins, but it was wrong because the two ponies that moved sausages got purple shells. Acceptance rates by adults were also significantly different when *huozhe* appeared in the

antecedent clause (7% *Yes*) versus the consequent clause (100% *Yes*;  $Z = -3.74, p < .0001$ ). There were no significant differences in the pattern of responses between groups. Table 3 provides the percentage of subjects' logical responses to the test sentences in Experiment 2.

The data provide evidence that 3–5-year-old Mandarin-speaking children were aware of the semantic universal that *huozhe* licenses a conjunctive entailment when it appears in the antecedent clause<sup>12</sup> but not in the consequent clause. Therefore, Mandarin-speaking children, like adults, accessed different truth conditions of disjunction when it appeared in the two clauses of conditional statements in parallel with the asymmetric truth conditions assigned to disjunction and conditionals in classical logic. This, in turn, suggests that children understood the different semantic properties of the two conditional clauses, i.e., the antecedent clause as a downward entailing context versus the consequent clause as a nondownward entailing context.

7. EXPERIMENT 3

The main goal of Experiment 3 is to address an issue that remains following the previous two experiments. Essentially, it is important to rule out the possibility that many of the findings from Experiments 1 and 2 could be explained without resorting to complex semantic properties such as the inclusive-*or* interpretation of disjunction and downward entailment. A far simpler possibility needs to be addressed, namely that children confuse disjunction for conjunction. In fact, exactly this possibility has been suggested in the literature on logical reasoning (Paris 1973). Experiment 3 was designed to clarify this issue. The experiment adopted the same methodology and testing procedures as Experiment 2. The experimental hypothesis, again based on logical nativism, is that children would be adultlike and distinguish between disjunction and conjunction in both the antecedent clause and the consequent clause of *ruguo*-conditional sentences.

TABLE 3  
Percentage of Children's and Adults' Logical Responses to the Test Sentences in Experiment 2

<i>Sentence type</i>	<i>Logical response</i>	<i>Children (N = 30)</i>	<i>Adults (N = 15)</i>
Disjunction in the Antecedent Clause (false) e.g., <i>If a pony moves a corn or a sausage, then he will get a gold coin.</i>	NO	97	93
Disjunction in the Consequent Clause (true) e.g., <i>If a rabbit finds a jewel, then she will get a ball or a star.</i>	YES	91	100

<sup>12</sup>A reviewer proposed an alternative account of the subjects' rejection of test sentences like (11) *If a pony moves a corn or a sausage, then he will get a gold coin*, when disjunction appeared in the antecedent clause of *ruguo*-conditionals. Specifically, a conditional is falsified when the antecedent is true and the consequent is false. In our design, the antecedent clause was true across conditions in Experiment 2 to ensure that it was felicitous for the subjects to judge the truth value of the whole conditional statement (see Footnote 6). So, children could reject (11), for example, by noticing that the consequent was falsified when the two ponies that moved sausages didn't receive gold coins. We cannot adjudicate between our account and the one proposed by the reviewer.

## 7.1. Participants

Participants were 29 monolingual Mandarin-speaking children ranging in age from 3;11 to 5;06, with the mean age of 4;11. The children were recruited from the Blue Sky Art Kindergarten in Changsha, China. All of the children passed the warm-up trial and participated in the main sessions. In addition, 15 adult native Mandarin speakers were tested as controls. All these adult subjects were Chinese international students at Macquarie University in Sydney, Australia.

## 7.2. Materials

Experiment 3 contained two main sessions. One session was comprised of six test sentences with the disjunction word *huozhe*, and the other was comprised of six test sentences with the conjunction word *he*. In each session, there were three test trials with *huozhe* or *he* in the antecedent clause and three with *huozhe* or *he* in the consequent clause. The stories had similar plots across conditions but used different characters. To reduce carryover effects resulting from the within subject design, subjects were tested with conjunction two weeks after they were tested with disjunction. Here is a typical test story in which the connective *huozhe* or *he* appeared in the antecedent clause of *ruguo*-conditionals.

This story is about five caterpillars that tried to obtain paintings from Big Bird—a famous painter. Big Bird had run out of color, and he promised to reward those caterpillars that could find color for him. He reminded the caterpillars that he would prefer some green leaves and red flowers for color. The caterpillars tried to find color for Big Bird. Finally, two caterpillars picked both a green leaf and a red flower, one caterpillar picked a green leaf, one caterpillar picked a red flower, and the last one picked a white leaf. Big Bird was very happy that the caterpillars collected color for him, and he presented his prizes: paintings and butterflies. Now, how would Big Bird reward these caterpillars?

At this point, the puppet made a prediction, in one of two conditions. One condition used the disjunction word *huozhe* in the antecedent clause, as in (13). The other used the conjunction word *he* in the antecedent clause, as in (14).

- (13) Ruguo maomaochong zhaidao xiaolüye **huozhe** xiaohonghua, ta jiu hui dedao hua.  
       if caterpillar pick green leaf or red flower he then will get painting  
       ‘If a caterpillar picks a green leaf **or** a red flower, then he will get a painting.’
- (14) Ruguo maomaochong zhaidao xiaolüye **he** xiaohonghua, ta jiu hui dedao hua.  
       if caterpillar pick green leaf and red flower he then will get painting  
       ‘If a caterpillar picks a green leaf **and** a red flower, then he will get a painting.’

Following the puppet’s prediction, the story continued. It turned out what actually happened was that Big Bird rewarded the two caterpillars that picked both a green leaf and a red flower with paintings, and he gave butterflies to the two caterpillars that picked only one of them, whereas the caterpillar that picked the white leaf received nothing from Big Bird. Note that, resembling Experiment 2, we employed a group of multiple characters, with the purpose of testing children’s understanding of *huozhe* and *he*, in similarly complicated situations where their knowledge of “conjunctive entailment” was revealed. As soon as the final outcome was revealed, the puppet repeated the prediction.



The two types of test sentences were expected to evoke different judgments from the child subjects. Specifically, children were expected to judge sentence (13), with *huozhe* in the antecedent clause, to be false because the caterpillars that picked either a green leaf or a red flower (but not both) received butterflies, rather than paintings. By contrast, children were expected to judge sentence (14), with *he* in the antecedent clause, to be an accurate description of the story because the caterpillars that picked both a green leaf and a red flower received paintings. So, if children distinguished between *huozhe* and *he*, they should reject (13) and accept (14). However, if children misunderstood *huozhe* as *he*, they should accept both (13) and (14).

The remaining test trials assessed children's ability to distinguish *huozhe* from *he* in the consequent clause of *ruguo*-conditionals. Here is a typical story:

This story is about a dolphin, a crocodile, and a swordfish that went to the Prince's home to play a hard game called "walking out of the water maze." The Prince encouraged them to try by saying "I will reward anyone that can walk out of the maze." He prepared a lot of prizes, including three crowns, three butterflies, and three stars. The three animals tried their best, and finally each of them walked out of the maze. Now, what kind of prizes will they receive?

At this point, the puppet predicted the prizes that the dolphin or the crocodile would receive, using two filler sentences (one true and one false), such as *Ruguo xiaohaitun zouchu migong, ta jiu hui dedao huangguan* 'If the dolphin walks out of the maze, then he will get a crown.' After the subject judged the filler sentences, the puppet produced a test sentence in one of two conditions. One condition had the disjunction word *huozhe* in the consequent clause, as in (15). The other condition had the conjunction word *he* in the consequent clause, as in (16).

- (15) *Ruguo xiaojianyu zouchu migong, ta jiu hui dedao hudie huozhe huangguan.*  
 if sword fish walk out maze he then will get butterfly or crown  
 'If the sword fish walks out of the maze, then he will get a butterfly **or** a crown.'
- (16) *Ruguo xiaojianyu zouchu migong, ta jiu hui dedao hudie he huangguan.*  
 if sword fish walk out maze he then will get butterfly and crown  
 'If the swordfish walks out of the maze, then he will get a butterfly **and** a crown.'

The story continued, with the Prince rewarding a butterfly to the swordfish. The puppet repeated the prediction after the final outcome was revealed. Note that sentence (15) used disjunction in the consequent clause in a context in which one disjunct was true. This compensated Session 2, Experiment 1, by testing the TF/FT condition in a felicitous context of the prediction mode (see Footnote 10).

If children distinguished between *huozhe* and *he*, they should produce different responses to these two types of test sentences. Specifically, they should accept sentence (15) with *huozhe* in the consequent clause because the swordfish obtained one of the objects that were mentioned in the two disjuncts.<sup>13</sup> But they should reject sentence (16), with *he* in the consequent clause, on the grounds that the sword fish should have received both a butterfly and a crown. However, if children misinterpreted *huozhe* as *he*, they may produce the same responses to both test sentences (15) and (16), i.e., by rejecting both sentences on the grounds that the swordfish only received one object rather than the two objects mentioned in the test sentences.

<sup>13</sup>To remove possible order effect, one of the three test sentences with *huozhe* in the consequent clause was true in virtue of the first disjunct, and the other two test sentences were true because of the second disjunct.

In addition, there were two control sentences (one true and one false in each session). These were conditional statements without disjunction. There were also four filler trials, i.e., simple positive sentences with future tense (one true and one false in each session), in order to evoke an equal number of *Yes* and *No* responses.

### 7.3. Results and Discussion

All subjects produced correct answers to the filler sentences, but six subjects wrongly accepted the false control sentences, and their data were excluded from the subsequent analysis. The final sample contained 23 children between the ages of 3;11 and 5;11, with a mean age of 4;11.

The main finding was that the subjects produced different responses to sentences with *huozhe* versus *he*. When *huozhe* or *he* appeared in the antecedent clause, children's acceptance rate for the test sentences with *he* was significantly higher than for those with *huozhe* (*he*: 93% versus *huozhe*: 13%,  $Z = -4.16$ ,  $p < .0001$ ). A similar response pattern was produced by adults (*he*: 100% versus *huozhe*: 2%,  $Z = -3.77$ ,  $p < .0001$ ). Subjects rejected the sentences with *huozhe* in the antecedent clause for the right reason. For example, in response to (13), they pointed out that the caterpillars that picked either a green leaf or a red flower (but not both) received two butterflies, rather than paintings. Moreover, when *huozhe* or *he* appeared in the consequent clause, children's acceptance rates were significantly higher for sentences with *huozhe* than for those with *he* (*huozhe*: 87% versus *he*: 12%,  $Z = -4.14$ ,  $p < .0001$ ). Adults accepted sentences with *huozhe* in the consequent clause 100% of the time, but none of them accepted sentences with *he* in the same position. Again, subjects generally rejected the test sentences for the right reason. For example, in response to sentence (16), they pointed out that the swordfish only received a butterfly, not both a butterfly and a crown. No significant differences were found between children and adults across all the four test conditions. Table 4 summarizes the percentage of subjects' logical responses to the test sentences in Experiment 3.

The findings suggest that 3–5-year-old Mandarin-speaking children, like adults, correctly distinguished between disjunction and conjunction when these logical connectives appeared in the two clauses of conditional statements. In particular, when disjunction appeared in the antecedent clause, in which the conjunctive entailment of disjunction was generated, children didn't misunderstand it as conjunction, so they treated *huozhe* and *he* differently. Moreover, children's acceptance of sentences with disjunction in the consequent clause lent additional weight to the interpretation of children's responses in Session 2 of Experiment 1—children had access to the full range of inclusive-*or* truth conditions for disjunction when it appeared in the consequent clause of conditional statements, a nondownward entailing context. Again, this logical interpretation of disjunction in the consequent clause did not stem from a misunderstanding of disjunction as conjunction.

## 8. GENERAL DISCUSSION

This study investigated 2–5-year-old Mandarin-speaking children's interpretation of the disjunction word *huozhe* (and the conjunction word *he*) in the two clauses of *ruguo*-conditional statements, i.e., in the antecedent clause versus the consequent clause. The purpose was to assess whether or not the interpretation of logical connectives in child language mirrors their

TABLE 4  
Percentage of Children's and Adults' Logical Responses to the Test Sentences in Experiment 3

<i>Sentence type</i>	<i>Logical response</i>	<i>Children (N = 23)</i>	<i>Adults (N = 15)</i>
Disjunction in the Antecedent Clause (false) e.g., <i>If a caterpillar picks a green leaf or a red flower, then he will get a painting.</i>	NO	87	98
Conjunction in the Antecedent Clause (true) e.g., <i>If a caterpillar picks a green leaf and a red flower, then he will get a painting.</i>	YES	93	100
Disjunction in the Consequent Clause (true) e.g., <i>If the sword fish walks out of the maze, then he will get a butterfly or a crown.</i>	YES	87	100
Conjunction in the Consequent Clause (false) e.g., <i>If the sword fish walks out of the maze, then he will get a butterfly and a crown.</i>	NO	88	100

corresponding counterparts in classical logic. Moreover, when considering the input children are exposed to, we ask how they acquire the meanings of these logical connectives. Our findings are summarized as follows. Experiment 1 revealed that children assigned an inclusive-*or* interpretation to disjunction in both the antecedent clause and the consequent clause of conditional statements, whereas adults assigned an exclusive-*or* interpretation to disjunction in the consequent clause. Experiment 2 revealed that children were aware of the semantic universal that disjunction licenses a conjunctive entailment when it appears in the antecedent clause, but not in the consequent clause. Experiment 3 demonstrated that children's knowledge in the previous two experiments was not due to a confusion between disjunction and conjunction.

Our findings challenge the usage-based account of the acquisition of the meanings of logical connectives (Morris 2008; see Goldberg 2006; Tomasello 2003), according to which the initial meanings children assign to logical connectives are limited to their simple nonlogical uses, without formal representations. Instead, the results reveal young children's adherence to the logical concepts of disjunction and conditionals in Mandarin Chinese, suggesting that the interpretation of these logical connectives in child language at least sometimes conforms to classical logic (Crain 2008, 2012; Crain & Khlentzos 2008, 2010; Crain, Gualmini & Meroni 2000; see Noveck 2001). More precisely, the experimental findings from Experiment 1 add incremental evidence to logical nativism that children initially assign an inclusive-*or* interpretation to disjunction in the antecedent clause in which adults generally endorse the same interpretation (Gualmini, Crain & Meroni 2000). Moreover, in the consequent clause in which adults' interpretation is influenced by the implicature of exclusivity, children's interpretation is still guided by the logical interpretation of inclusive-*or*. Children's adherence to inclusive-*or* in both the two conditional clauses runs counter to the assumption on the usage-based account, according to which children's initial knowledge of disjunction is restricted to the nonlogical meaning of exclusive-*or* (Morris 2008). In addition, the findings from Experiment 2 indicate that children are aware of the asymmetric

truth conditionals of disjunction in the two conditional clauses, in parallel with the way disjunction and conditionals interact in classical logic. This in turn implies that children decompose a conditional sentence into an antecedent clause and a consequent clause, as in classical logic, and that they understand the different entailment properties of the two conditional clauses. Finally, it is evident from Experiment 3 that children's knowledge of disjunction (i.e., inclusive-*or*) and its asymmetric truth conditions does not stem from a mistaking of disjunction as conjunction. This yields supplementary evidence to logical nativism that the truth condition assigned to conjunction in child language mirrors closely that assigned to the corresponding conjunction operator in classical logic.

The critical issue is how children detect these logical concepts of connectives at an early stage of language development. The answer we provide is directly related to a further distinction between logical nativism versus the usage-based learning account. Our findings pose a series of challenges for the usage-based account, which seems incapable of explaining a number of children's linguistic behaviors. First, the usage-based account owes us an explanation for why children initially assign disjunction an inclusive-*or* interpretation, mirroring the logical disjunction operator but not the adult input that is overtly more consistent with the exclusive-*or* interpretation. The most striking contrast is the mismatch between children's adherence to the basic semantics of inclusive-*or* versus adults' exclusive-*or* interpretation in the consequent clause. Presumably, this finding comes about because adults, but not children, compute a scalar implicature of exclusivity when disjunction appears in nondownward entailing contexts (Chierchia et al. 2001, 2004; Gualmini et al. 2001; Su 2013). Second, even given most optimistic assumptions of children's abilities to form abstract generalizations based on the input, the usage-based learning models would be hard-pressed to explain children's awareness of the different truth conditions of disjunction in the antecedent clause versus the consequent clause, since the distinction is in interpretation but not in distribution (Crain, Khlentzos & Thornton, 2010; see Chierchia 2004). Third, taken together with prior research (e.g., Boster & Crain 1993; Crain et al. 2002; Goro & Akiba 2004; Goro, Minai & Crain 2005; Gualmini & Crain 2002; Gualmini, Crain & Meroni 2000; Gualmini, Meroni & Crain 2003; Jing, Crain & Hsu 2005; Notley, Thornton & Crain 2012; Notley et al. 2012; Su & Crain 2013; Su, Zhou & Crain 2012), the observation that across languages young children assign logical connectives (e.g., *or*, *if*, *and*) the same meanings that the corresponding connectives are assigned in classical logic, either (a) against apparently disparate evidence or (b) at the quasi absence of the decisive evidence from their local linguistic communities, poses a serious challenge to the usage-based account, which would anticipate cross-linguistic variations based on children's linguistic experience in their local language communities (Goldberg 2003, 2006). Until all these challenges are solved, we contend that the findings of the present study offer support for the view that the meanings of logical connectives in human languages are innately specified, as part of the human genome (Crain 2008, 2012; Crain & Khlentzos 2008, 2010).

One might ask whether or not the 16 *huozhe*-utterances and 27 *ruguo*-utterances reported from the CHILDES database constitute sufficient evidence for children to establish the mapping between natural language disjunction and conditionals and their corresponding counterparts in classical logic. The answer is surely negative. For one thing, the *huozhe*-utterances in adults' daily usage are superficially more compatible with an exclusive-*or* interpretation than an inclusive-*or* interpretation; therefore, it certainly seems more possible for children to conjecture that disjunction is exclusive-*or*. However, as empirically confirmed in this study (Session 2, Experiment 1) and elsewhere in other studies (e.g., Goro & Akiba 2004; Jing, Crain & Hsu 2005;

Notley et al. 2012; Su 2013), children adhere to the logical representation of inclusive-*or*, even in circumstances in which adults assign an exclusive-*or*. For another, the *ruguo*-utterances in adult input provide no evidence for the entailment properties of the antecedent clause versus the consequent clause. Nevertheless, despite the paucity of the relevant linguistic evidence in the input, children are aware of the different entailment properties of the two conditional clauses, in line with their knowledge of several other linguistic structures differing with respect to the semantic property of downward entailment (e.g., Boster & Crain 1993; Goro, Minai & Crain 2005; Gualmini, Meroni & Crain 2003; Notley, Thornton & Crain 2012; Su & Crain 2013; Su, Zhou & Crain 2012). It seems that when children establish the mapping between the meanings assigned to logical connectives in human languages and the meanings assigned to the corresponding expressions in classical logic, children do not base this mapping on the input they receive. This invites the conclusion that young children are guided by Universal Grammar to project meanings rather than learn them (Crain 2008, 2012; Crain & Khlentzos 2008, 2010).

In this study, we have investigated whether or not the vocabulary of human languages contains expressions corresponding to classical logic. One of our particular interests is whether human languages generate similar entailments in sentences with disjunction, as in one of de Morgan's laws in classical logic:  $\neg(A \vee B) \Rightarrow \neg A \wedge \neg B$ . Future research can explore children's knowledge of other de Morgan's laws in child language. For example, logical negation also generates the bidirectional entailments of two de Morgan's laws:  $\neg(A \vee B) \Leftrightarrow \neg A \wedge \neg B$  and  $\neg(A \wedge B) \Leftrightarrow \neg A \vee \neg B$ . One can consequently ask whether or not children understand that the corresponding expressions (such as the negation word English *not* and Mandarin *meiyou*) in human languages generate similar entailment relations as in classical logic. Assuming that future research will continue to find that the meanings of logical expressions emerge early in language development, across typologically different languages, this will build an even stronger case for the logical nativist hypothesis—that children draw upon an innate logical vocabulary at the initial stages of language acquisition.

## ACKNOWLEDGMENTS

Portions of the data were presented in a doctoral thesis submitted to Macquarie University. The author wishes to express the deepest gratitude to Professor Stephen Crain for his guidance throughout this study and for his support in bringing this work into fruition. The author extends her gratitude to professors Thomas Lee, Rosalind Thornton, and Drew Khlentzos for valuable suggestions during the early stages of this study and to Professor Lin-Yan Su for her solid support in the completion of this work in China. Finally, the author wishes to thank all the anonymous reviewers and the editors (especially professors Jeffrey Lidz and Julien Musolino) for their insightful comments and suggestions on earlier versions of the paper. Needless to say, all errors and omissions remain the sole responsibility of the author.

## FUNDING

This work was supported by two Australian Research Council Discovery Grants (DP1096160 & DP0879842) and was also partially supported by one Chinese National Science Grant (81171291).

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*Submitted 12 July 2011*

*Final version accepted 25 June 2013*